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Identification of the Cognitive, Psychomotor, and Psychosocial Skill Demands of Uninhabited Combat Aerial Vehicle (UCAV) Operators *

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Abstract

Unmanned Combat Air Vehicles extend tactical the range of aircraft mission options. Although certain cultural barriers exist with regard to complete acceptance of remotely controlled aircraft. the UCAV will become an essential part of many Air Forces in the years to come. A critical factor to the success of UCAV missions is the optimal selection of operators. This paper explores options for improving the selection and training of UCAV operators and reviews test that may be useful toward an improved screening system. Emphasis is placed upon the assessment of decision-making ability. personality factors. and related cognitive attributes with recommendations for future research directions. In the interest of identifying a valid UCAV test battery that will reliably predict successful completion of both UCAV training and operational performance, program managers are encouraged to consider funding selection programs that evaluate psychological measures of individual differences, in addition to the standard psychomotor coordination measures.

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Introduction

Uninhabited combat air vehicles (UCAVs) are predicted to dominate the battlespace in the coming century. They will be intelligent, autonomous, systems of systems. UCAVs are envisioned to conduct a myriad of missions including: surveillance and reconnaissance, precision strike, suppression of enemy air defense (SEAD) and several logistical (resupply) efforts. Military planners expect the UCAV to be a transparent extension of existing manned combat systems. This goal will only be attained though effective operator selection and crew systems integration (CSI).

Very little research has been conducted to assess the operator selection and crew systems integration (CSI) requirements essential to understanding the human limitations necessary for optimizing the interfaces of these complex systems. Current concepts of uninhabited air vehicle control are based on the remotely placed operator as a controller of the vehicle's flight and require several crewmembers to control/manage a single air vehicle. Future concepts envision the remote operator as more of a "mission manager", providing primarily operational mission information to the vehicle, including information concerning target acquisition and weapons release, and may require a single operator to effectively control/manage several air vehicles simultaneously. In order to achieve force multiplication using UAVs, yet reduce the number of dedicated personnel afloat or aloft, the ability for a single operator to simultaneously control/manage more than one of these vehicles is necessary.

UCAVs are going to be a fourth class of vehicle that will contain many of the same operator/system problems that have existed for years in the other three (manned aviation, cruise missiles, and UAVs). However, it will also create many issues that haven't been addressed in prior systems.

Greater automation of the vehicle system will allow the operator/mission manager to focus attention on the mission rather than on tasks associated with vehicle flight as is typically the case with the existing legacy UAVs. Current systems rely upon human intervention to control the air vehicle. The US Navy's Pioneer UAV requires an *external pilot* to manually control the flight surfaces of the vehicle during takeoff and landing through an interface derived from that of a remote controlled airplane. Physical dexterity and hand-eye coordination are taxed through the use of this system. The US Air Force's Predator UAV requires control by a rated pilot. Rudder pedals, throttle and joystick are housed in the ground control station. Once again, physical dexterity is required.

UCAVs are envisioned as the next generation of "smart UAVs", which will place greater cognitive demands on the operator/mission manager. UCAVs are envisioned to be autonomous with little or no manual control required. Performance of tasks that are likely to be required include:

> managing/controlling multiple air vehicles' missions; recognizing and dealing with degraded system functionality; regaining situational awareness after loss of vehicle data links; interpreting displays containing multiple UCAV perspectives; and shift of system control to other team members or control stations.

It should be apparent then, that the emphasis will be on the operator/manager's cognitive ability to assimilate and/or disseminate dynamic, complex data in order to make rapid and effective strike/attack decisions. The role of psychomotor abilities in UCAV operations is likely to be diminished.

Selection of operators for UCAV missions will have to consider abilities in the cognitive as well as psychomotor domains. Additionally, questions that must be considered include the following:

Is the operator a pilot or non-pilot?

What are the skill requirements (performance requirements)?

What should be the team composition?; and

What aspects of previous training will have positive and/or negative impacts on transfer of training?

UAV Operator Selection

In response to a series of costly Pioneer UAV craft losses attributed to human error. Biggerstaff, et al conducted a UAV operator task analysis. As a result of the study, both medical and operator selection test recommendations were proposed (1).
Several performance-based selection test measures were identified and evaluated in the study to predict UAV operator training outcome. Although the sample size in the study was small (N=14), significant findings were reported between a composite of multitask tracking scores and UAV performance. The following is a brief summary of the tests used in the study (1). Detailed descriptions of the tests can be found in Helton, Nontasak, and Dolgin, (2).

Psychomotor Task (PMT). The PMT consists of stick, rudder pedal, and throttle control tasks and measures eye, hand, foot coordination.

Horizontal Tracking (HT). In this task, the subject is required to learn a one-dimensional compensatory tracking task.

Dichotic Listening Task (DLT). The DLT assesses individual differences in the ability to focus attention

PMT/DLT Combination. As a measure of time-sharing abilities. the PMT can be combined with the DLT in order to assess shared resources. As mentioned above, the PMT and DLT are administered initially as single tasks and then combined to result in increasingly complex. simultaneously performed. multiple-task conditions.

Manikin Test. The Manikin Test measures spatial orientation and reaction time.

Digit Cancellation Task. The subject is visually presented with a random number between 1 and 9 on the computer screen that is erased and then followed immediately with another number. Although this task is essentially a measure of short-term memory and reaction time. it can also be used as a distractor.

Digit Cancellation and Horizontal Tracking The horizontal tracking and digit cancellation tasks are combined for a measure of dual-task performance.

Time Estimation Task. The Time Estimation Task measures visual tracking and time estimation abilities The horizontal tracking task is included as part of this task as a distractor. According to Biggerstaff et al (1998). the task measures of time and distance estimation abilities are critical to the external pilot's control of the Pioneer.

Although limited to psychomotor/spatial testing. the test battery identified in the Naval Aerospace Medical Research Laboratory study is a good first step toward establishing UCAV operator assessment and selection.

Psychomotor and spatial abilities-type tests have been used (or proposed for use) in one form or another with different populations since World War I (3). They have successfully been used to predict training outcome and have been shown to account for significant variance. In particular, psychomotor coordination tests have been demonstrated to reliably account for significant amounts of variance in the prediction of flight training success (4). However, as operational requirements and technology have become more complex and demanding, variables such as basic reaction time, spatial ability and eye-hand-foot coordination become less task relevant.

While the relevance of psychomotor variables has declined, there has been an increase in the relevance of high level cognitive functions for UCAV operations. As previously described, UCAVs place tremendous demands on multi-tasking, prioritizing, sequencing, and vigilance. Unlike the psychomotor performance area, where there are numerous tests available for measuring abilities, there are relatively few tools designed for measuring multi-tasking, prioritizing and sequencing. Computer-based cognitive testing, including virtual reality-based testing approaches, appears to be the most promising approach for assessing the abilities of UCAV candidates and incumbent operators. Computerization provides for excellent standardization of test stimuli, time intervals, maximal control over item presentation, capacity to present degraded stimuli, suitability for presentation of simultaneous mental tasks (in the same or different sensory modalities), and accurate recording of response speeds and accuracy to all tasks being presented.

CogScreen-Aeromedical Edition is a computerized cognitive screening test originally designed for the U.S. Federal Aviation Administration as an instrument for evaluating pilots' neurocognitive fitness-to fly. The selection of the tests for CogScreen-AE was based on existing task analysis of the cognitive and psychomotor demands of flying. In fact much of the pioneer work conducted by the Walter Reed Army Institute of Research and the Navy Aerospace Medical Research Laboratories was incorporated into the development of CogScreen-AE. Studies have demonstrated

that CogScreen-AE is not only sensitive to changes in brain functioning resulting from trauma. substance abuse or illness, but that it is also a strong predictor of flight performance.

In one study, the frequency and severity of flight performance violations for a substantial group of captains was measured by flight data recorders. Specifically, Yakimovich, Strongin, Govorushenko. Schroeder, and Kay presented a paper at the 65th Annual Scientific Meeting of the Aerospace Medical Association in 1994. The investigators reported that variables from a small number of CogScreen-AE tests, partciularly those measuring working memory, mental flexibility, and divided attention (e.g., Dual Task, Shifting Attention, Divided Attention, Pathfinder, and backward Digit Span), were able to account for between 30% and 45% of the varianice in the performance index, e.g.. flight violations per 100 hours of flight. Hoffmann et al. found a strong relationship between these measures and performance in the cockpit, including CRM (5). Encouraging results from these and other studies has led the US Air Force to include CogScreen-AE as a component of their Enhanced Flight Screen for aviators (6). Subsequently a large number of commercial airlines in the US and elsewhere began using CogScreen-AE for pilot selection and to establish a baseline against which to evaluate their cognitive functioning at some later time.

UCAV: Cognitive Testing

While the relevance of psychomotor variables has declined in pilot selection, there has been an increase in the relevance of high level cognitive functions. As described previously, UCAV operations place tremendous demands on multi-tasking, prioritizing, sequencing, and vigilance. Unlike the psychomotor performance area, where there are numerous tests available for measuring abilities, there are relatively few tools designed for measuring these higher level cognitive abilities.

Computer-based cognitive testing, including virtual reality-based testing approaches, appears to be the most promising approach for assessing the abilities of UCAV candidates and incumbent operators. Computer-based testing provides:

- excellent standardization of test stimuli and time intervals;
- offers maximal control over item presentation;
- capacity for presenting degraded stimuli;
- suitability for presenting simultaneous mental tasks (in the same or different sensory modalities); and
- accurate recording of response speeds and response accuracy.

CogScreen-Aeromedical Edition is a computerized cognitive screening test originally designed for the U.S. Federal Aviation Administration (FAA) as an instrument for evaluating pilots' neurocognitive fitness-to fly. The selection of the tests for CogScreen-AE was based on existing task analysis of the cognitive and psychomotor demands of flying. In fact much of the pioneer work conducted by the Walter Reed Army Institute of Research and the Navy Aerospace Medical Research Laboratories was incorporated into the development of CogScreen-AE. Studies have demonstrated that CogScreen-AE is not only sensitive to changes in brain. functioning resulting from trauma, substance abuse and illness, but that it is also a strong predictor of flight performance.

UCAV: Personality Testing

CogScreen-AE, and similar computer-based tests, may be helpful in assessing the cognitive abilities relevant to UCAV operations, however, operator selection also needs to address the personality characteristics and relational attributes of prospective operators. In a stressful and

demanding environment, the importance of interactional style, judgement and decision-making can make the difference between a successfully completed mission and the loss of a million dollar resource. In fact, it is precisely these measures of individual differences in personality that predict outcomes in operational tasks.

Efforts to improve personality assessment include computerization, development of verification and correction scales, keying certain items against specific criteria, masking the dimension of interest, and the application of factor analysis to isolate more specific trait categories (7, 8, 9). Historically, there have been validity problems and lackluster results associated with the use of personality tests in selections. This is largely due to the obvious psychopathology orientation of the tests used in past personnel selection research.

Commercial airlines have used clinical personality tests as well as interviews for pilot selection. Meta-analyses and related research provide compelling evidence that personality traits are predictive of training and job performance across a wide range of occupational settings (10, 11, 12). In fact, it has been demonstrated that personality profiles differ with

USAF pilot role: fighter, bomber, tanker (13).

There are a number of personality tests that may prove useful in UCAV operator selection. Two examples are as follows:

Revised NEO Personality Inventory:

The NEO represents a new approach to measuring the Big Five personality measures. It is based on extensive research that shows that a consistent set of dimensions of normal

personality across the psychological literature. These are referred to these as Neuroticism. Openness. Agreeableness. Conscientiousness and Extroversion (14). A significant correlation was found between agreeableness and performance on measures of crew resource management (CRM) (5).

FIRO-B:

The Fundamental Interpersonal Relation Orientation (FIRO-B) generates 6 scores (0-9) indicating expressed and wanted needs in the areas of Inclusion. Control. and Affection. Scores from 0 to 1 are considered extremely low and scores from 8 to 9 are considered extremely high scores. According to Schutz. the basic idea is that "every person orients himself (or herself) in characteristic ways toward other people. and that knowledge of these orientations allows for considerable understanding of individual behavior and the interaction of people" (15). In another study. "group warmth". a derivative of FIRO-B Inclusion and Affection scales. was significantly related to the commercial effectiveness of teams (16). The FIRO-B was also evaluated as a measure of team compatibly with U.S. Air Force AWACS weapons director teams (17). Although their results. in general. did not support the hypothesis that high compatibility. as measured by the FIRO-B. would be associated with better simulated AWACS performance. crew compatability was a factor in team performance for several of the teams in the study. According to Shutz. the FIROB has been successfully used for "improving self-awareness. teamwork. morale. and productivity in such organizations a Proctor & Gamble. AT&T. NASA. Amdahl Corporation. the Swedish Army and about 100 companies in Japan (16).

UCAV: Tests of Basic Aviation Knowledge and Intelligence

Multi-tasking ability is required to operate under stress and respond to multiple stimuli. However, to perform the UCAV tasks described in the background section of this paper, the operator must be able to formulate an idea, make a correct decision and respond. This requires two additional measures, g, or basic intelligence, and aviation knowledge. The task of operating multiple vehicles at a distance and deriving necessary information from systems and instrumentation is an abstract exercise filled with the interpretation of abstract concepts. Facility with abstract, verbal, mathematical and spatial reasoning is expected to be as important as it has been in aviation (18). It is also clear from the work of Hoffmann et al. that knowledge of aerodynamics, engineering and navigation, at a conceptual level, is likely to be predictive of performance for these operators (5). Tests in these content areas need to be constructed to assess the ability of the operators to actually apply principles of engineering, and aerodynamics to solve novel problems. This type of problem solving is quite different form the use of check lists for troubleshooting equipment failures.

Model for Developing a Test Battery for UCAV Operator Selection

The abilities required for UCAV operations fall into five categories:

g;

psychomotor ability;

cognitive ability;

personality; and

conceptual knowledge.

An effective selection test battery will need to use adaptations of existing tests in these five areas, or

use newly developed tests. These abilities can be viewed as orthogonal: high psychomotor ability does not predict high conceptual knowledge or even high cognitive ability. Measures in each of these ability areas (used individually and in combinations) have been shown to predict success in flight training and line operations.

The steps to develop such a test battery are well established:

- identify relevant knowledge, skills, abilities, and personality attributes as well as specific performance objectives that operators are required to achieve;
- define the environment in which they will be expected to work;
- identify and link knowledge, skills, abilities, and personality characteristics that are associated with success at those activities and in those conditions;
- select or develop measures of those knowledge, skills, abilities, and personality parameters;
- develop performance measures of job related activities;
- test a representative sample of individuals believed capable of learning and performing the job of UCAV operator, (clearly this would have to occur on simulators ahead of production of the UCAVs. Note that such research would be informative of the human factors limitations of specific UCAV designs);
- train operators;
- observe operator performance in training and on the job;
- correlate performance with test measures and build a mathematical model that relates success on the job, and success in training, with performance on tests;
- choose cut scores to maximize true positives and minimize false positives.

Discussion

In addition to the abilities discussed in this paper, there are others that may be important to consider as part of a selection assessment battery. For example, the operator's willingness to rely on a computer for decisions may be a particularly important factor for the UCAV operator functioning in a virtual reality like environment. As UCAV systems evolve it may become apparent that the individual's style of interacting as a member of a team, may also be a critical selections variable. Ultimately, the objective is to develop a comprehensive UCAV test battery that includes not only the basic psychomotor coordination measures but one that measures all of the relevant personality and cognitive attributes. Development of a comprehensive assessment battery for UCAV operators is likely to result in benefits in UCAV system engineering as well.

References

(10). Barrick. M.R and Mount. M.K. The big five personality dimensions and job performance: A meta analysis. Personnel Psychology, 44. 1-26. 1991.

(1). Biggerstaff, S., Blower. D.J.. Portman. C.A.. and Chapman. A.D. The development and initial validation of the unmanned aerial vehicle (UAV) external pilot selection system. NAMRL 1398. Pensacola. FL: Naval Aerospace Medical Research Laboratory. 1998.

(6). Callister. J.D., King, R.E... and Retzlaff. P.D. Cognitive assessment of USAF pilot training candidates. Aviation. Space. and Environmental Medicine. 67. 1124-1129. 1996.

(14) Costa. Paul T.. Jr.. and McCrae. Robert R.. *Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO-FFI)*. Psychological Assessment Resources. Inc.. 1992.

(8). Dolgin. D.L. and Gibb. G.D. "Personality Assessment in Aviation Selection: Past, Present and Future." In R. Jensen (Ed.), Aviation Psychology: The International Contribution. London: Gower Publishing Group, 285-319. 1989.

(7). Dolgin. D. L., Shull. R.N.. and Gibb. G.D. Risk assessment and the prediction of student pilot performance. In R. Jensen (Ed.). Proceedings of the Fourth International Symposium of Aviation Psychology. *480-485*. 1987.

(2). Helton. K.T., Nontasak, T.. and Dolgin. D.L. Landing craft air cushion (LCAC) crew selection system Manual. NAMRL-92-4. Pensacola. FL: Naval Aerospace Medical Research laboratory. 1992.

(3). Hilton. T. F. and Dolgin. D. L. "Pilot Selection in the Military of the Free World." In R. Gal and A. D. Mangelsdorff (Eds.). The Handbook of Military Psychology Sussex. England. John Wiley and Sons. Ltd.. 81-101. 1991.

(5). Hoffmann. Carl C.. Hoffmann. Kathleen P.. and Kay Gary G.. The role that cognitive ability plays in CRM. *Collaborative Crew Performance in Complex Operational Systems*. 1998

(17). Kay. G.G. and Dolgin, D.L. Team compatibility as a predictor of team performance: Picking the best team. Proceedings of the 1st NATO Research and Technology Organization (RTO), Human factors and Medical Panel Symposium. 6-1 to 6-9. 1998.

(12). McHenry. J. Hough, L.M.. Toquam. J.L.. Hanson. M.A.. and Ashworth. S. Project A validity results: The relationship between predictor and criterion domains. Personnel Psychology. 43. 335-354. 1990.

(18). Ree. M.J.. and Carreta. T.R.. The central role of g in military pilot selection". Armstrong Laboratory. Human Resource Directorate. Manpower and Personnel Research Division. 1995.

(13). Retzlaff. P.D. and Gilbertini. M. Air force personality: hard data on the "right stuff". Multivariate Behavioral Research. 22. 383-399. 1987.

(10). Siem. F.M.. Carretta. T.R.. and Mercatante. T. Personality. attitudes. and pilot training performance: preliminary analysis. Air Force Human Resources lab. Manpoer and Personnel Division (AFHRL-TP-87-62). 1988.

(15). Shutz. W. "The Interpersonal Underworld: FIRO-A Three Dimensional Theory of Interpersonal Behavior". Palo Alto. California. Science and Behavior Books. Inc.. 1966 (ISBN: 0-8314-0011-0).

(16). Shutz. W. "Beyond FIRO-B-three new theory-derived measures-element B: behavior. element F: feelings. element 5: self". Psychological Reports. 70. 9 15-937. 1992.

(4). Street. D.R. and Dolgin. D.L. Computer-based psychomotor tests in optimal training track assignment of student naval aviators. NAMRL-1391. Pensacola. FL: Naval Aerospace Medical Research laboratory. 1994.

(11). Tett. R.P. Jackson. D.N. and Rothstein. M. Personality measures as predictors of job performance: A meta-analytic review. Personnel Psychology. 44. 703-742. 1991.